# The Scaling of Premixed Turbulent Flames

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# Objective

To understand the factors contributing to the consumption speed of premixed turbulent flames

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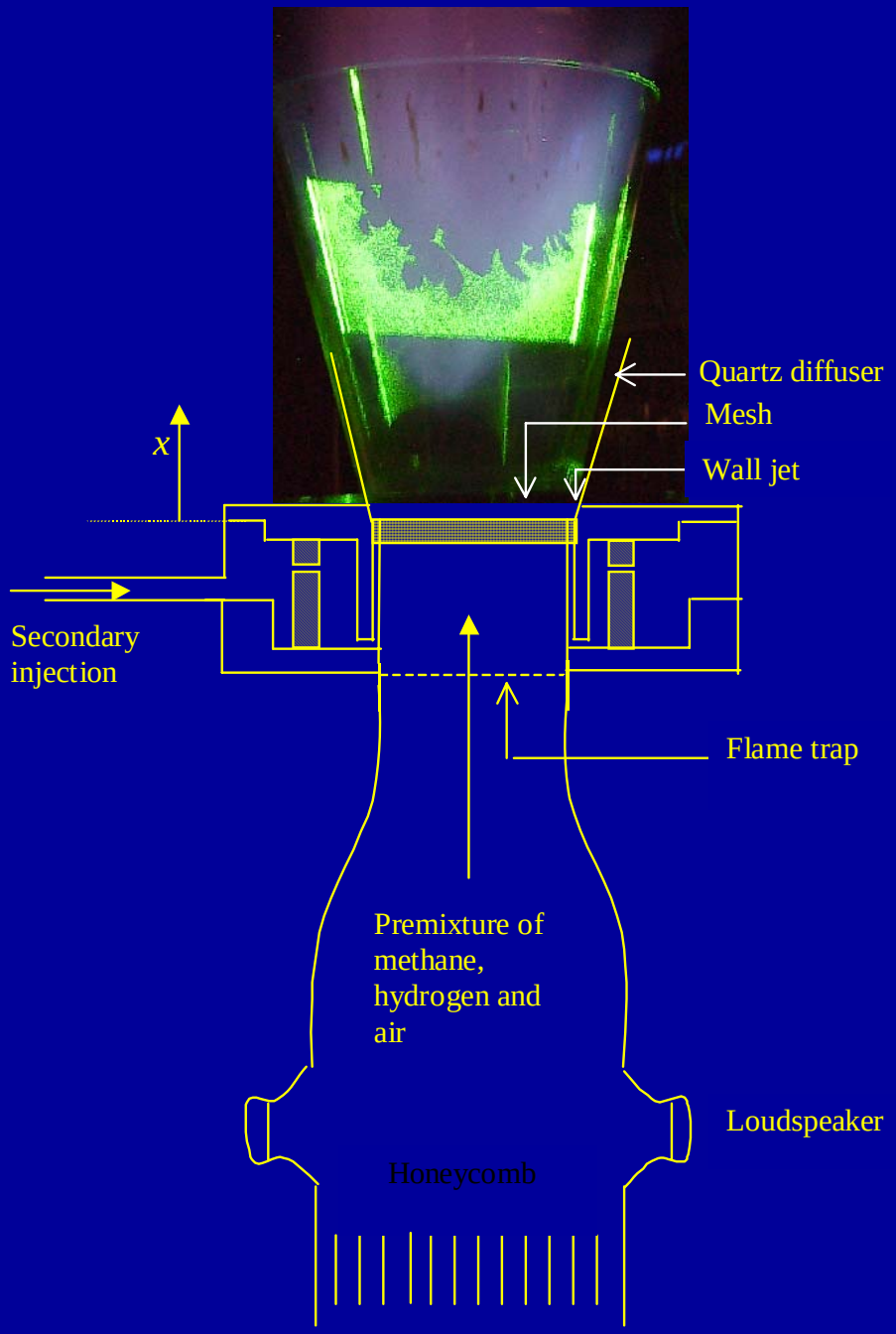
# Apparatus



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$$\frac{\dot{w}}{\rho_u S_{L0}} = \frac{S_c}{S_{L0}} = I_0 \int_{\xi_u}^{\xi_b} \Sigma(\xi) d\xi \quad \text{where} \quad I_0 = 1 - 0.28\, Ma\, Ka_\eta$$

[Bray & Cant, Proc Roy Soc A 434 (1991)]

$$\Sigma = 4\Sigma_{\max} \bar{c}\left(1 - \bar{c}\right)$$

$$\dot{w} \propto \Sigma \propto \frac{\partial \bar{c}}{\partial \xi} \quad \Rightarrow \quad \bar{c} = \left[1 + \exp\left(\frac{-4(\xi - \xi_m)}{\delta_T}\right)\right]^{-1}$$

$$\frac{S_c}{S_{L0}} = I_0 \Sigma_{\max} \delta_T$$

# Basis of Flame Surface Analysis

[Shepherd, Proc. Combust. Inst. 26 (1996) ]

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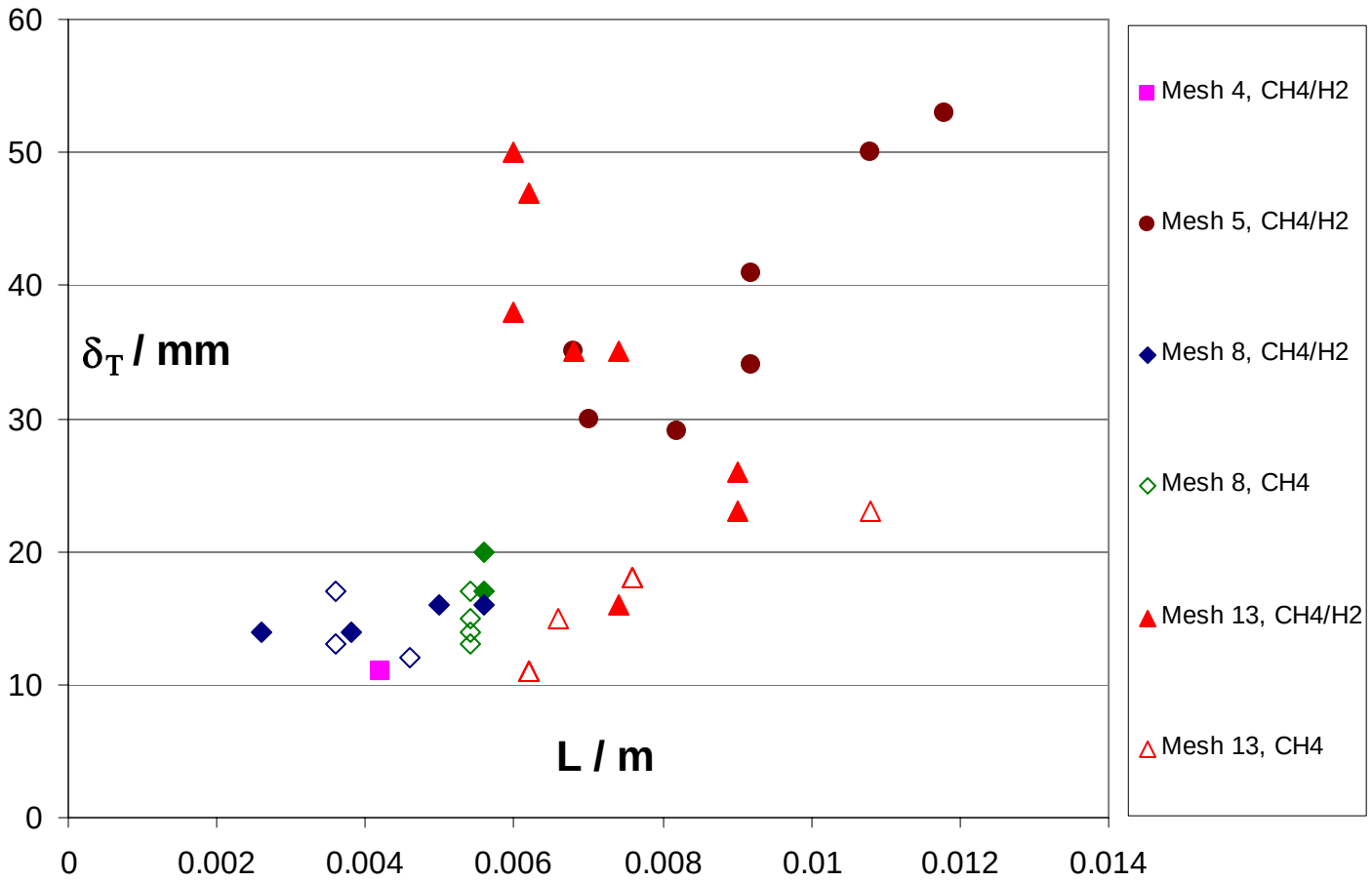
$$S_c, \Sigma_{\max}, \delta_T, I_0 \equiv f_{1,2,3,4}\{u', L, S_{L0}, \nu, \alpha, \alpha_m, \tau\}$$

or

$$\frac{S_c}{S_{L0}}, \Sigma_{\max} L, \frac{\delta_T}{L}, I_0 = F_{1,2,3,4}\left\{\mathrm{Re}_L, \frac{u'}{S_{L0}}, \mathrm{Pr}, Le, \tau\right\}$$

# Flame Parameter Dependencies




# Flame Brush Thickness Data

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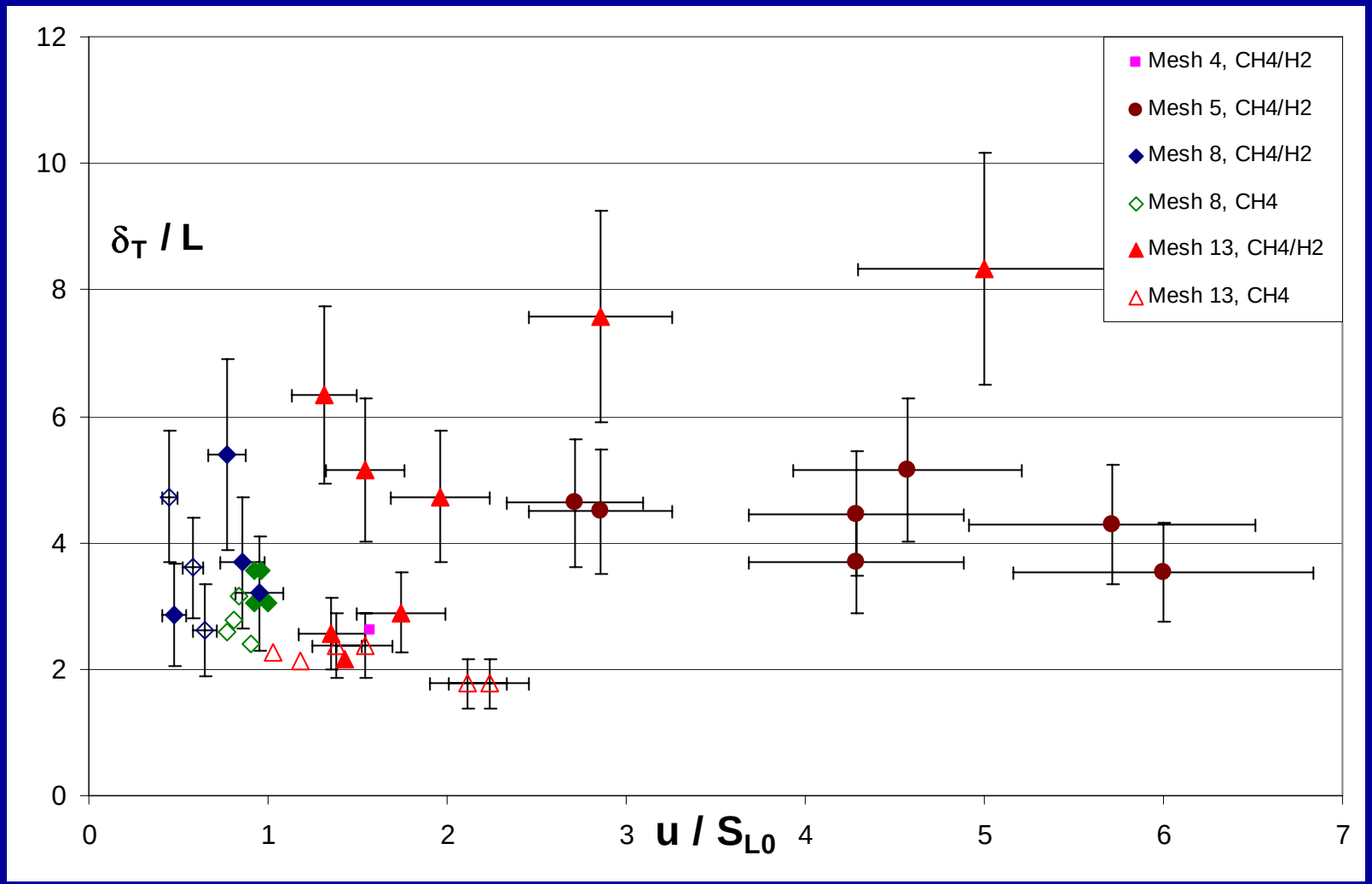


# Normalised Flame Brush Thickness Data

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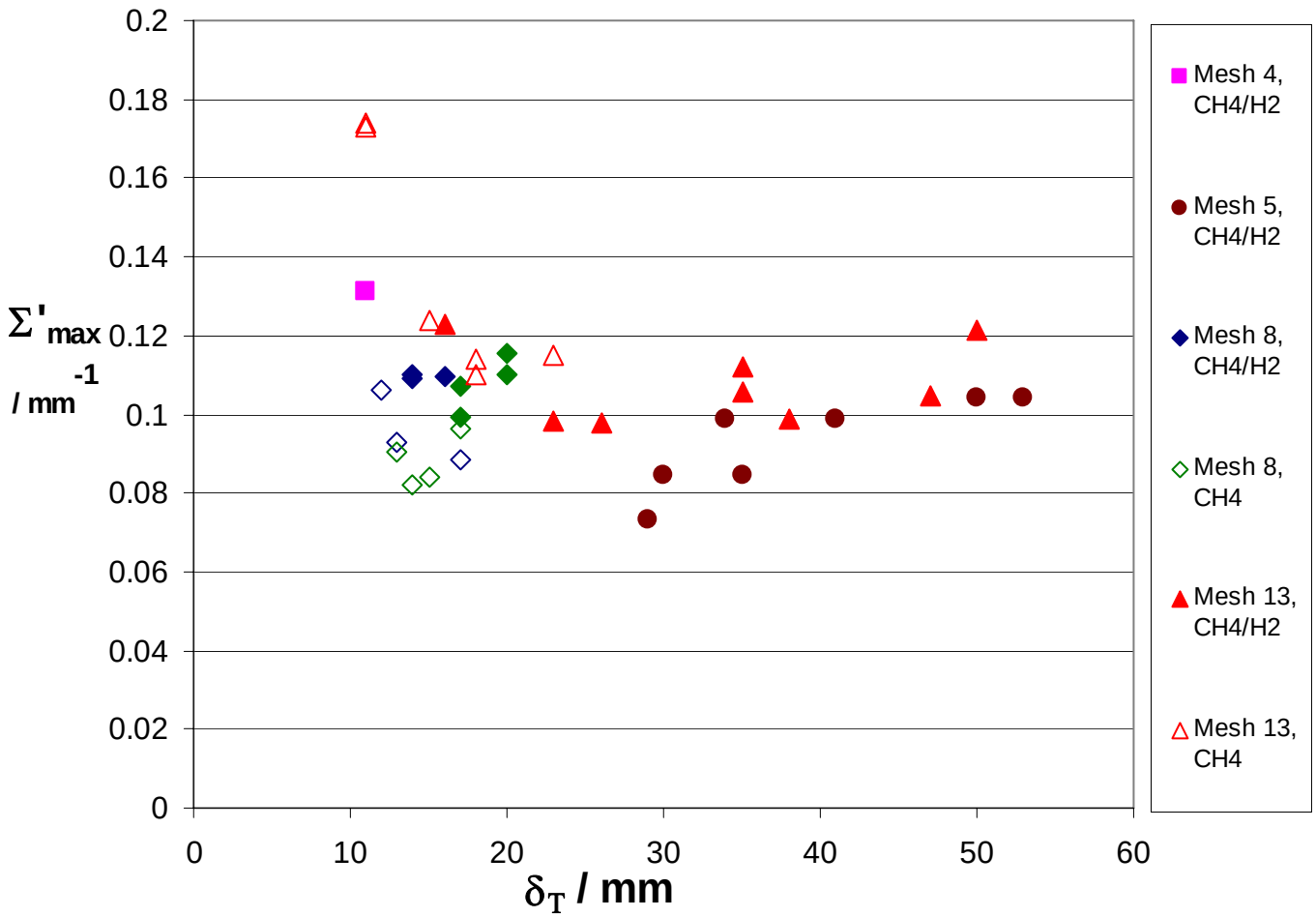
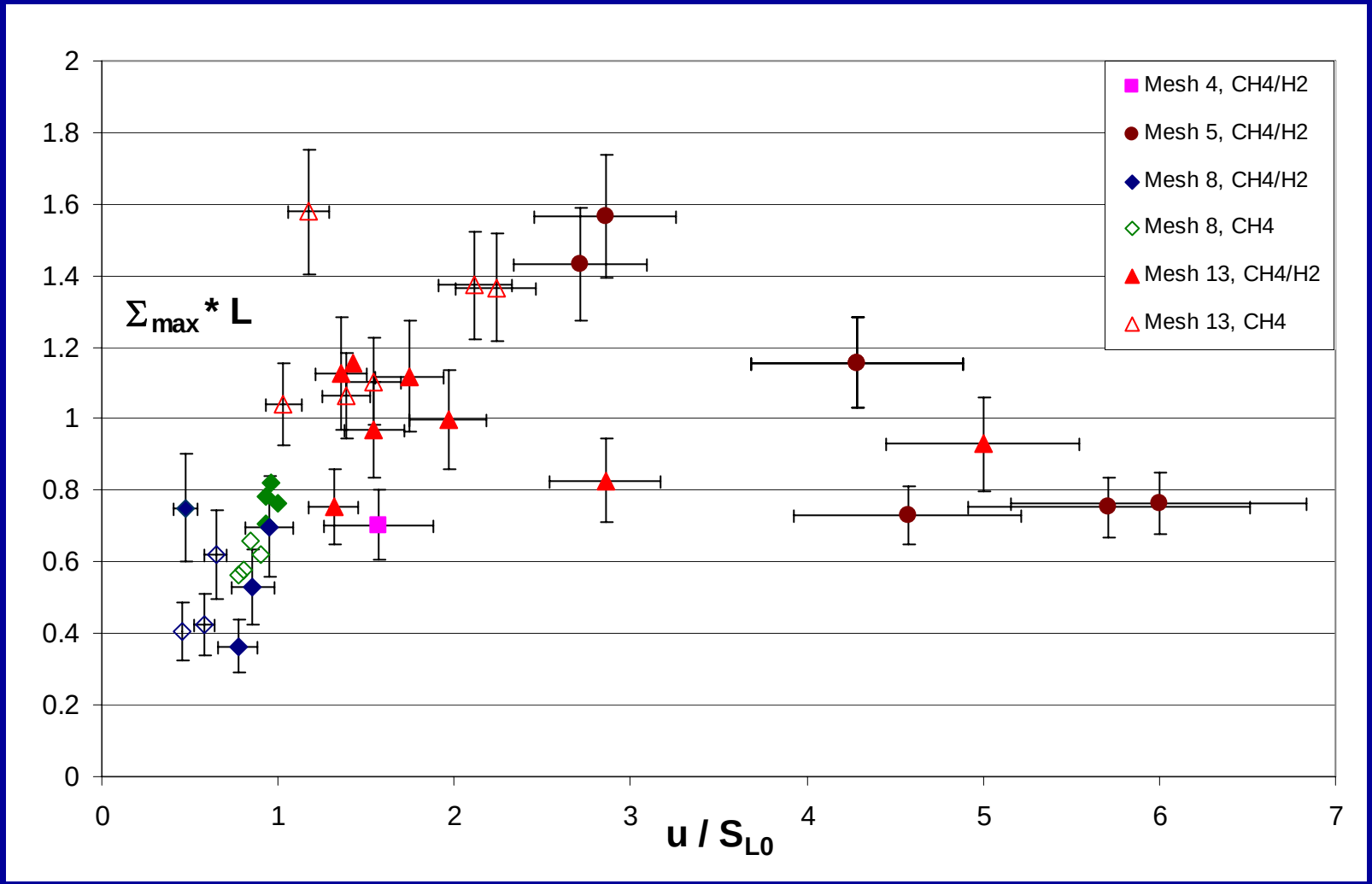
# Observations on the Flame Brush Thickness Data

- $\delta_T$ varies strongly with L, and linearly for a given mesh and fuel.
- $\frac{\delta_T}{L} \approx 4$ for one mesh with $CH_4/H_2$, independent of turbulence level.
- $\frac{\delta_T}{L} \approx 2$ for pure $CH_4$. Le dependence?

- c.f. $\frac{\delta_T}{L} \approx 1.5 - 1.8$ measured by Plessing et al. [Proc. Combust. Inst. 28(2000)] for $CH_4$ in their low swirl burner with $\frac{u'}{S_{L0}} > 3$




# 2-D Flame Surface Density Data




# Normalised 3-D Flame Surface Density

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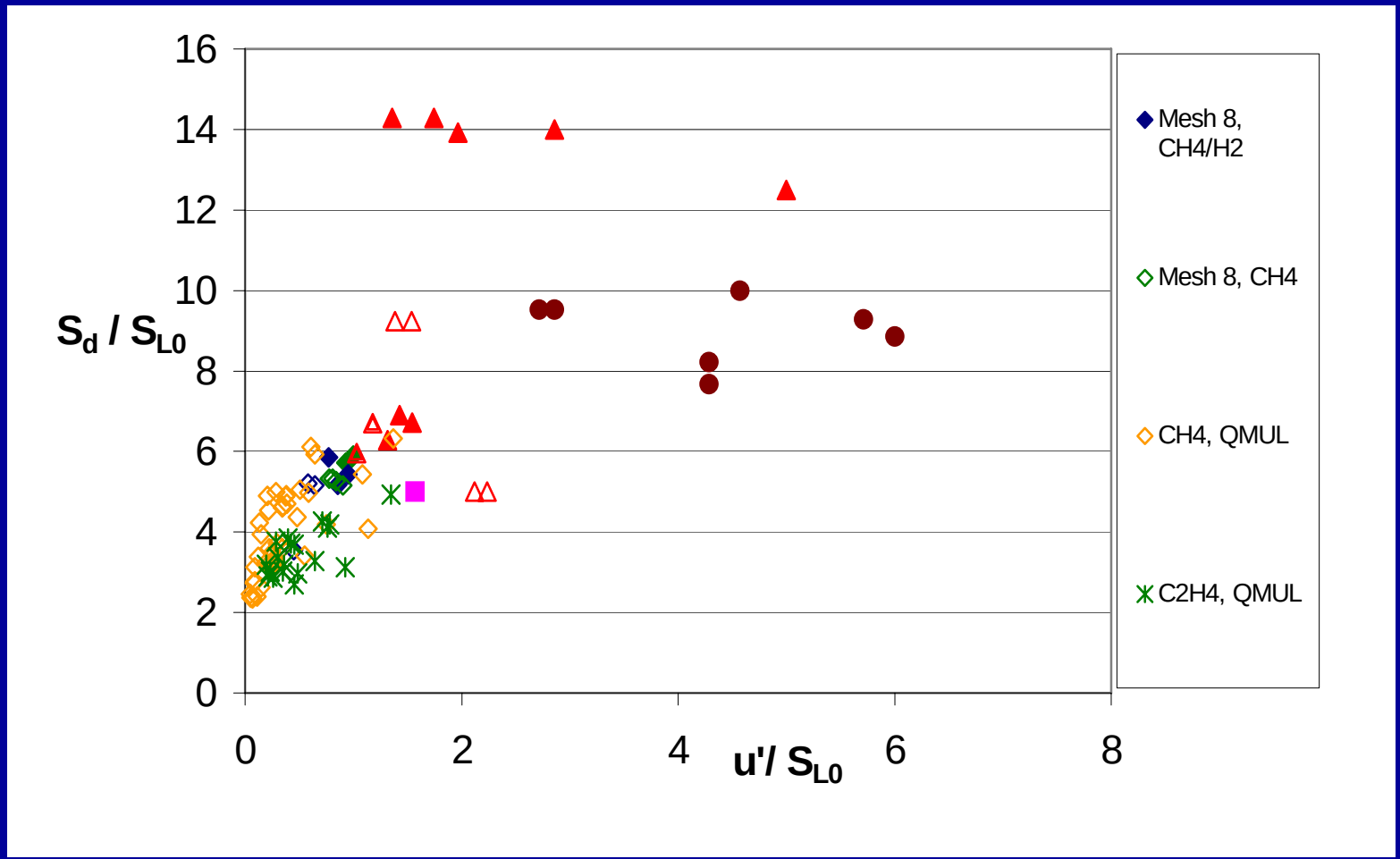
# Observations on the Flame Surface Density Data

- $\Sigma'_{\max}$ is almost invariant.
- $\Sigma_{\max} = 1.27\ \Sigma'_{\max}$ involves relatively little error (10% max)
- $\Sigma_{\max} L \approx 1 \; for \; \frac{u'}{S_{L0}} > 1$ independent of Le.
- c.f. $\Sigma_{\max} L \approx 1.5 - 3 \; for \; \frac{u'}{S_{L0}} > 3$ measured by Shepherd et al. [Proc. Combust. Inst. 29(2002)] in their low swirl burner




# Displacement Speeds Measured at Sandia and at QMUL

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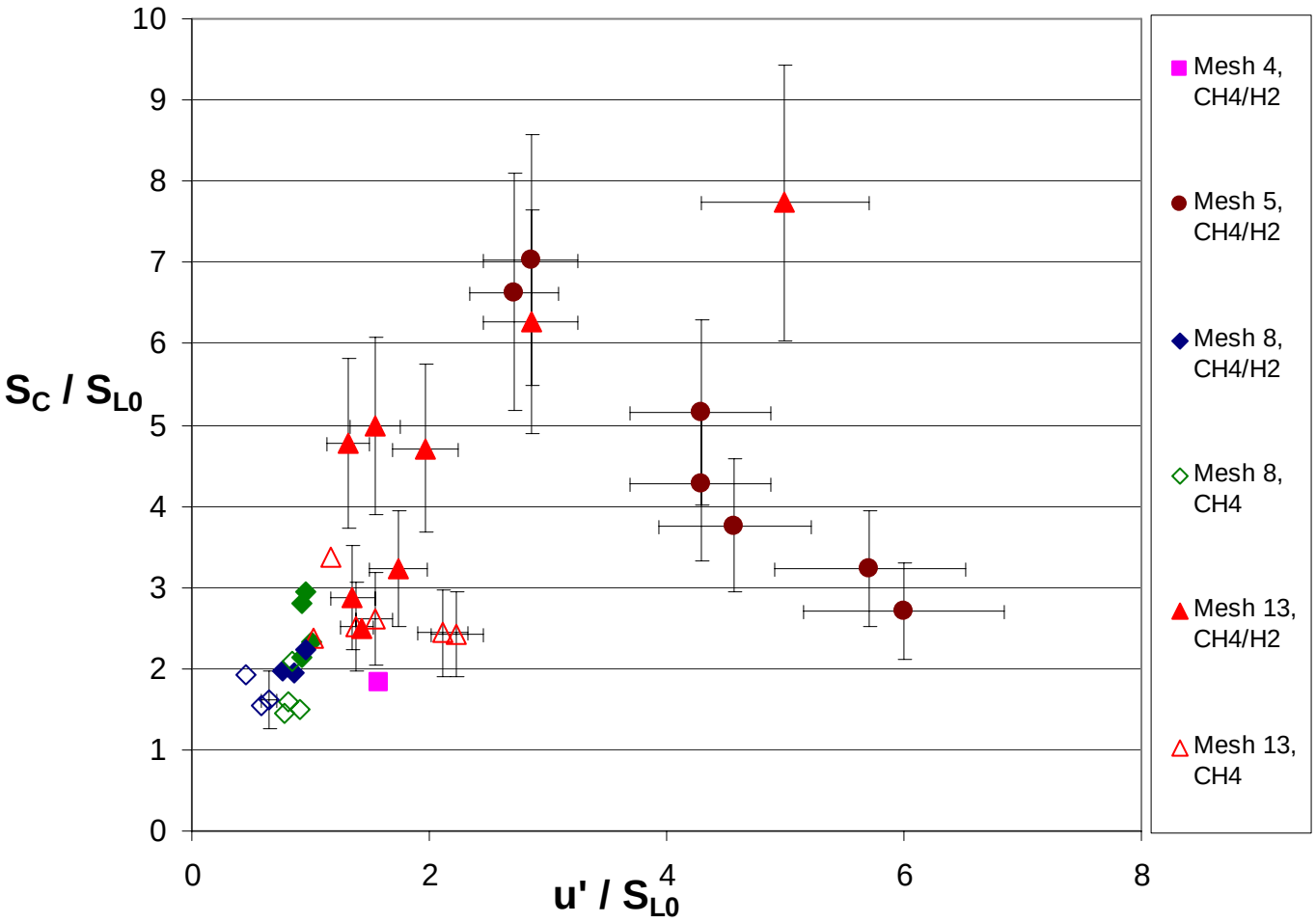
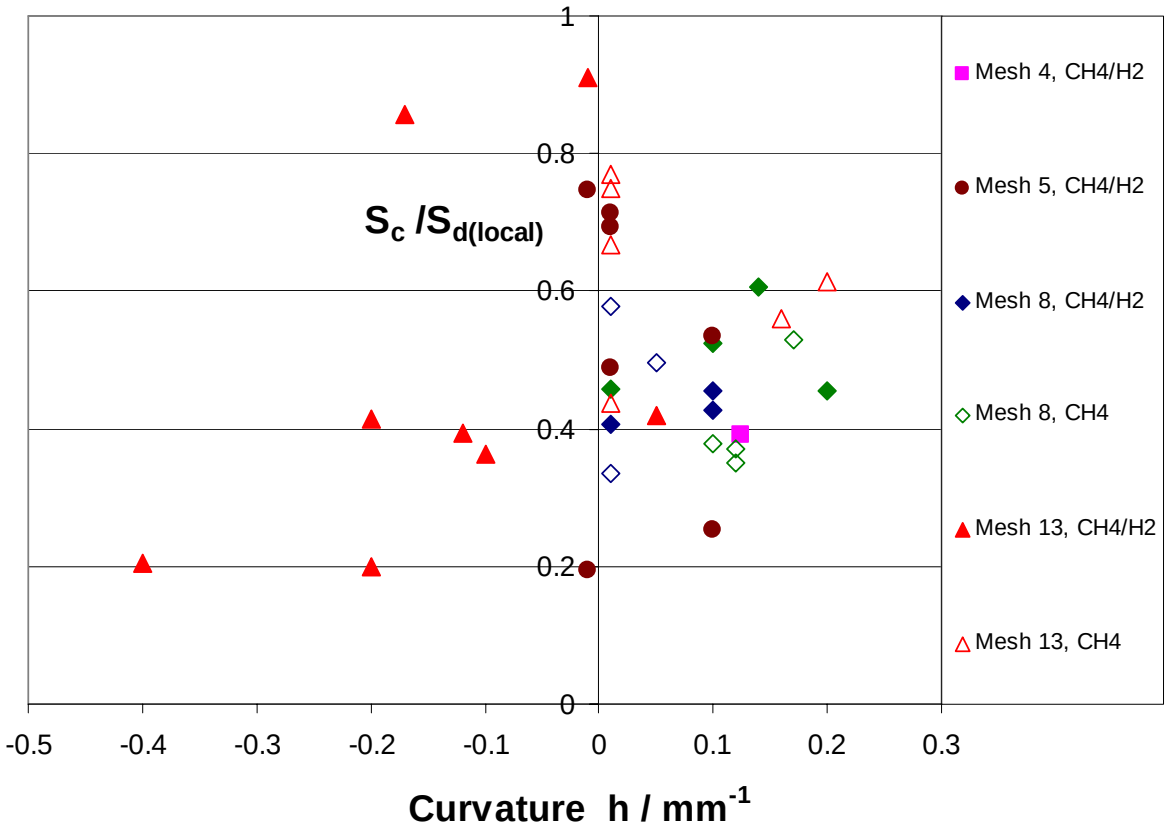



# Consumption Speeds




# Ratio of Displacement Speeds to Consumption Speeds as a Function of the Mean Flame Curvature

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# Observations on the Turbulent Burning Velocity Data

- Both displacement and consumption speeds appear to increase linearly up to $\frac{u'}{S_{L0}} \approx 3$ and then to decrease slightly.
- $\frac{S_d}{S_{L0}} \approx 3$ in the limit of no turbulence, due to Darrieus-Landau instabilities.

- The measured ratio of burning velocities $\frac{S_c}{S_d}$ is <1 even when there is no mean flame-front curvature.

- Very high values of $\frac{S_d}{S_{L0}}$ (>10) are associated with negative curvature.
- There are no measurements here or in the literature with $\frac{S_c}{S_{L0}} > 8$ .

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